HYDRO STATICS

PRESSURE MEASUREMENT

Pressure Measurement

Pressure Head

Pressure in fluids may arise from many sources, for example pumps, gravity, momentum, etc. Since $p = \rho g h$, a height of liquid column can be associated with the pressure p arising from such sources. This height, h, is known as the pressure head.

Example:

The gauge pressure in a water pipe is 50 kN/m^2, what is the pressure head?

$$p = \rho g h$$

$$h = \frac{p}{\rho g} = \frac{50 \times 10^3}{1000 \times 9.81}$$

$$\approx 5.1 \text{ m}$$

So the pressure at the bottom of a 5.1 m deep swimming pool is the same as the pressure in this pipe.

Pressure Measurement

Pressure Head

Pressure head represents the height of a column of homogeneous fluid of unit weight γ that will produce an intensity of pressure p.

$$h = \frac{p}{\gamma}$$

To convert pressure head (height) of liquid A to liquid B:

$$h_B = h_A \frac{s_A}{s_B} \text{ or } h_B = h_A \frac{\rho_A}{\rho_B} \text{ or } h_B = h_A \frac{\gamma_A}{\gamma_B}$$

To convert pressure head (height) of any liquid to water, just multiply its height by its specific gravity:

$$h_{water} = h_{liquid} * s_{liquid}$$

Pressure Measurement

Manometers

A manometer (or liquid gauge) is a pressure measurement device which uses the relationship between pressure and head to give readings.

In the following, we wish to measure the pressure of fluid in a pipe.

Piezometer

This is the simplest gauge. A small vertical tube is connected to the pipe and its top is left open to the atmosphere, as shown.

Pressure Measurement

Piezometer

The pressure at A is equal to the pressure due to the column of liquid of height h_1:

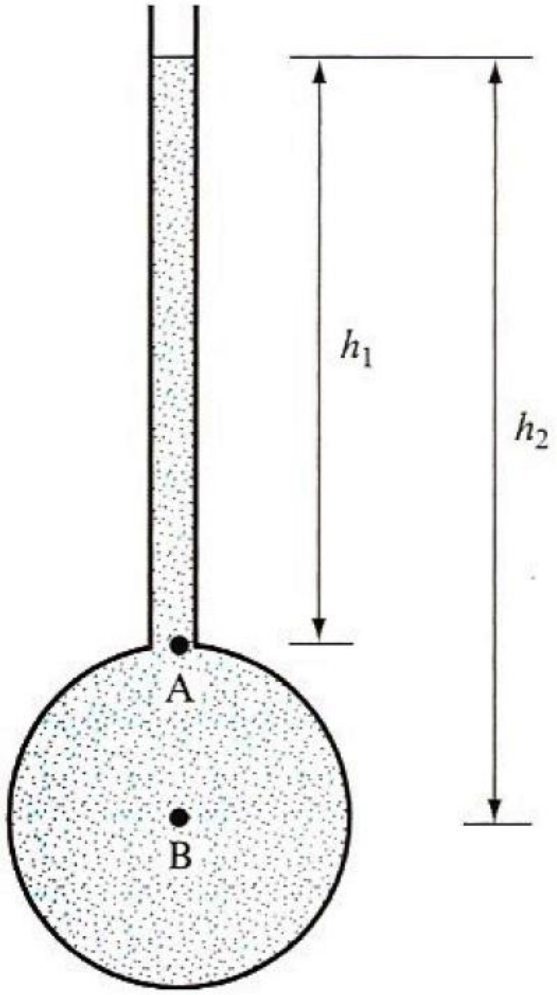
$$p_A = \rho g h_1$$

Similarly,

$$p_B = \rho g h_2$$

The problem with this type of gauge is that for usual civil engineering applications the pressure is large (*e.g.* 100 kN/m^2) and so the height of the column is impractical (e.g. 10 m).

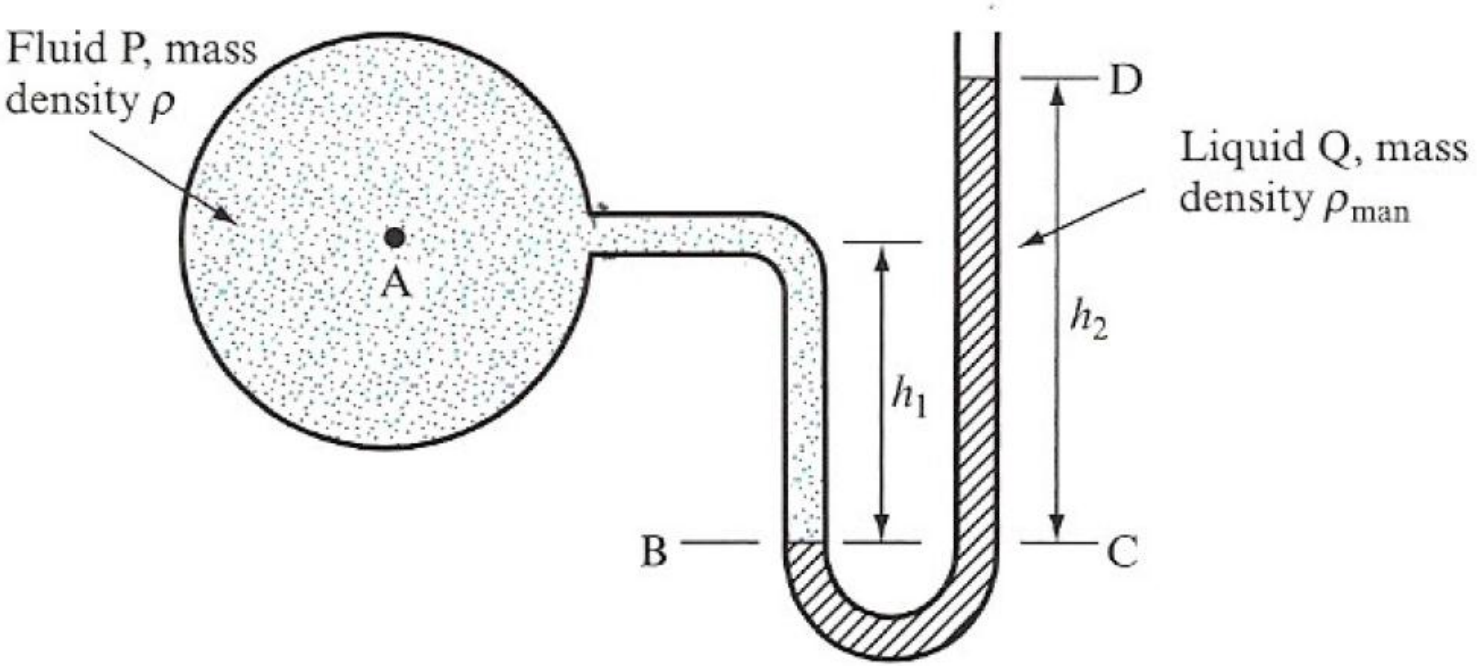
Also, obviously, such a gauge is useless for measuring gas pressures.



Pressure Measurement

U-tube Manometer (Open Type)

To overcome the problems with the piezometer, the U-tube manometer seals the fluid by using a measuring (manometric) liquid:



Pressure Measurement

U-tube Manometer

Choosing the line BC as the interface between the measuring liquid and the fluid, we know: Pressure at B, p_B = Pressure at C, p_C

For the left-hand side of the U-tube:

$$p_B = p_A + \rho g h_1$$

For the right-hand side:

$$p_C = \rho_{man} g h_2$$

Where we have ignored atmospheric pressure and are thus dealing with gauge pressures. Thus:

$$p_B = p_C$$

$$p_A + \rho g h_1 = \rho_{man} g h_2$$

$$p_A = \rho_{man} g h_2 - \rho g h_1$$

Notice that we have used the fact that in any continuous fluid, the pressure is the same at any horizontal level.

Pressure Measurement

Differential Manometer

To measure the pressure difference between two points we use a U-tube as shown:

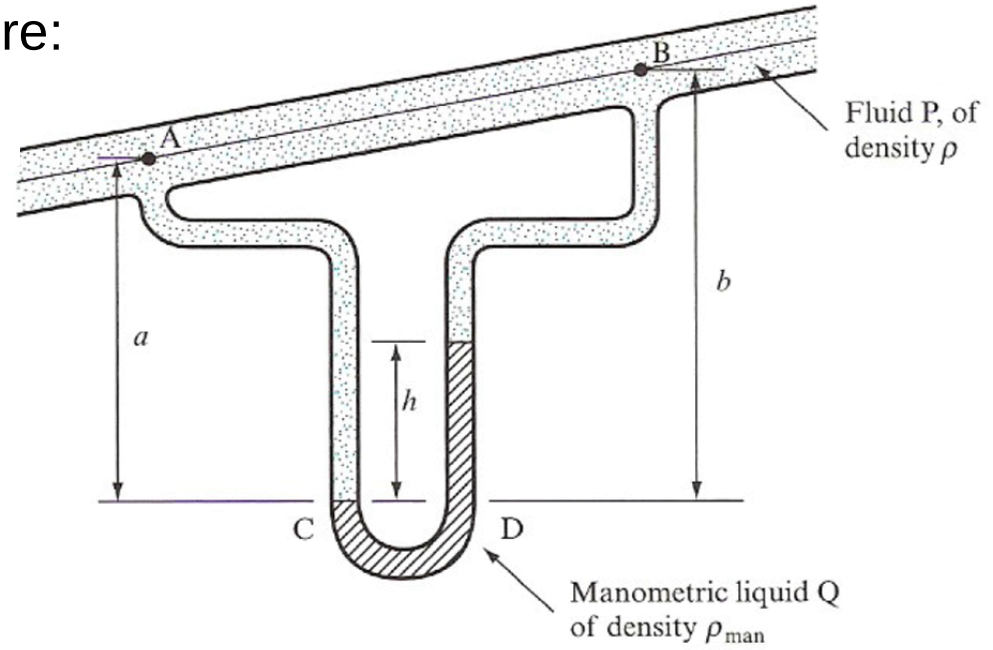
Using the same approach as before:

$$\text{Pressure at } C,\ p_C = \text{Pressure at } D,\ p_D$$

$$p_A + \rho g a = p_B + \rho g (b - h) + \rho_{man} g h$$

Hence the pressure difference is:

$$p_A - p_B = \rho g (b - a) + h g (\rho_{man} - \rho)$$

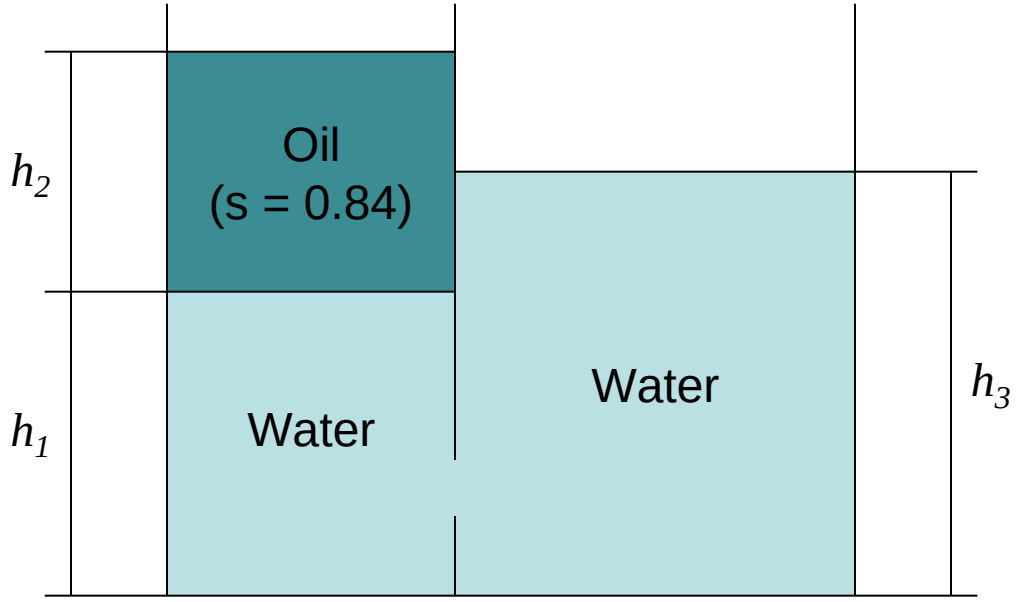


Pressure Measurement

Problem Set 3

Problem 1

For the tank shown in the figure, $h_1 = 3\ m$ and $h_3 = 4\ m$. Determine the value of h_2.



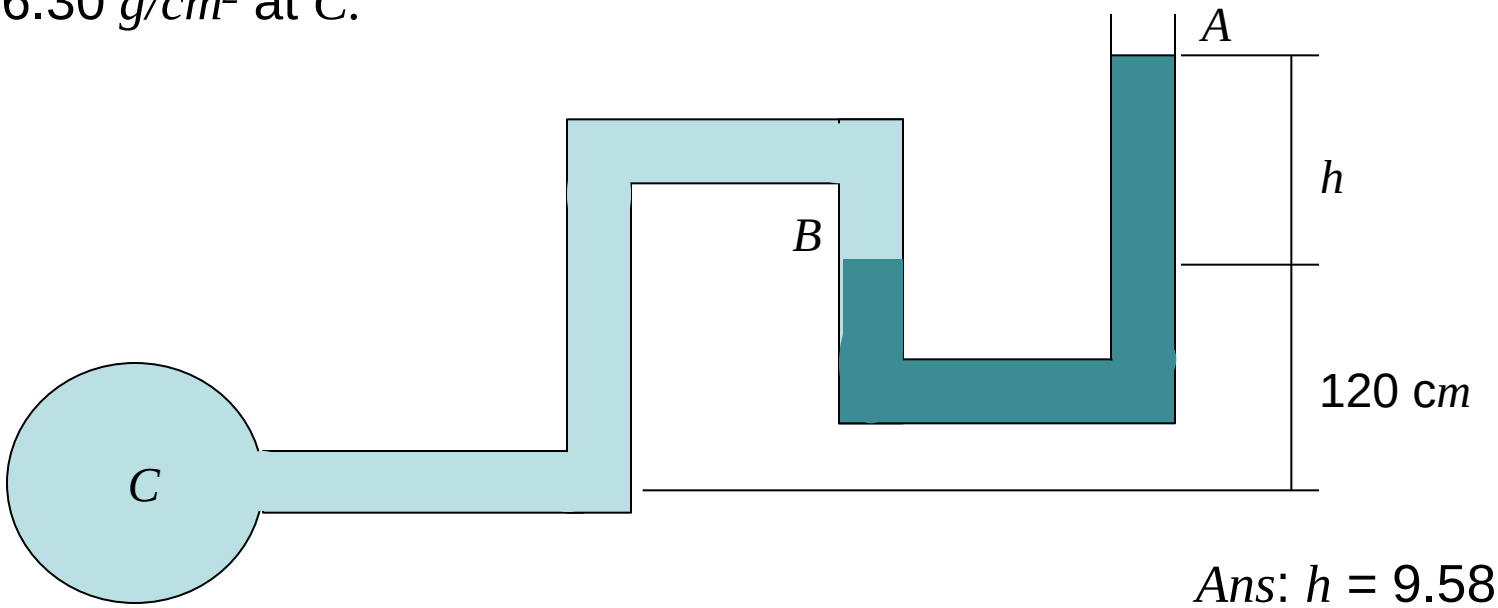
Ans: $h_2 = 1.19\ m$

Pressure Measurement

Problem Set 3

Problem 2

In the manometer shown, the fluid from A to B is mercury (s = 13.6) and from B to C is oil (s = 0.8). What height h of mercury will give a pressure of 226.30 g/cm^2 at C.



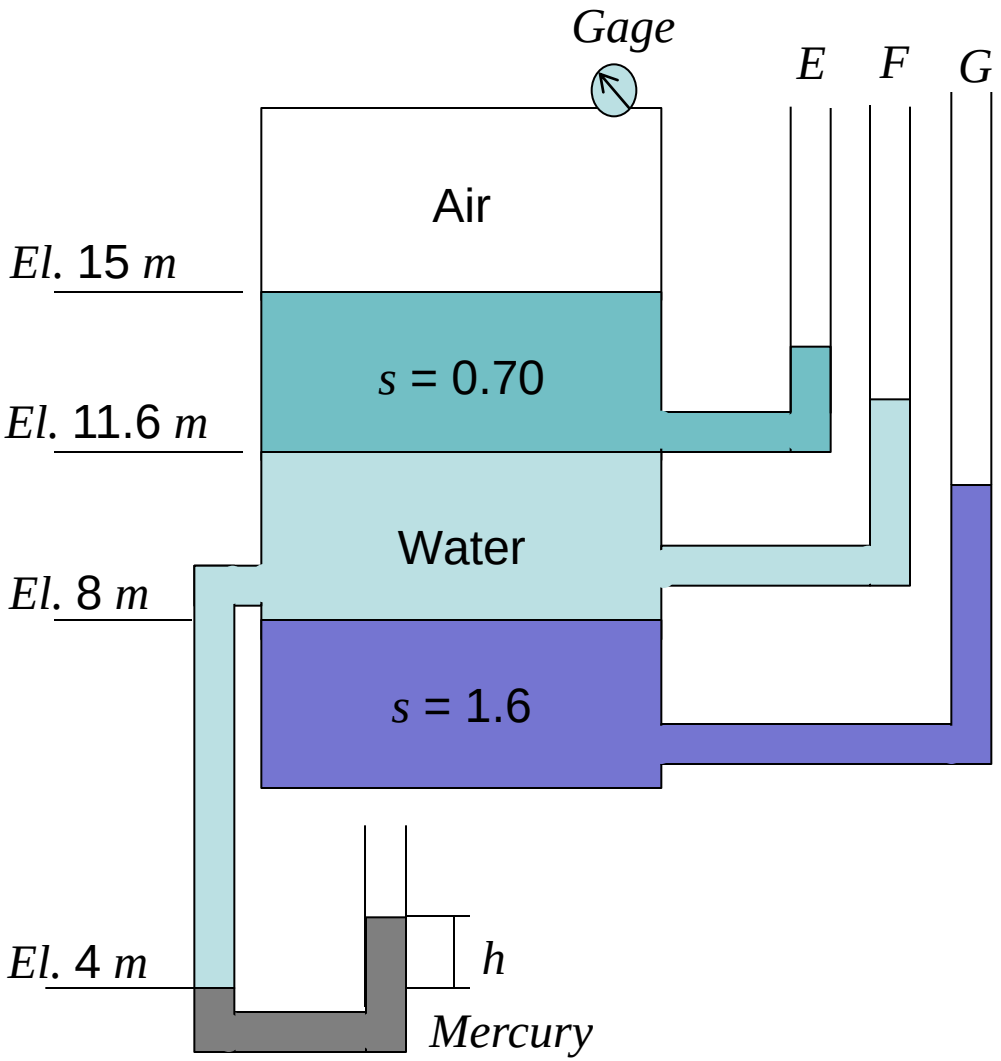
Ans: h = 9.58 cm

Pressure Measurement

Problem Set 3

Problem 3

For a gage reading of -17.2 kPa, determine the (a) elevations of the liquids in the open piezometer columns E, F, and G and (b) the deflection of the mercury in the U-tube manometer neglecting the weight of air.

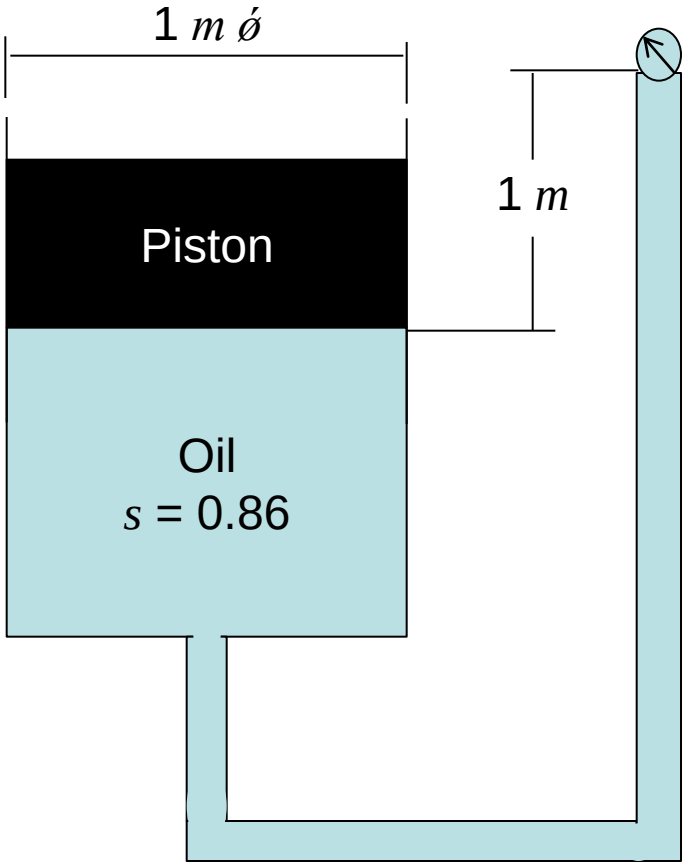


Pressure Measurement

Problem Set 3

Problem 4

For the configuration shown, calculate the weight of the piston if the pressure gage reading is 70 kPa.



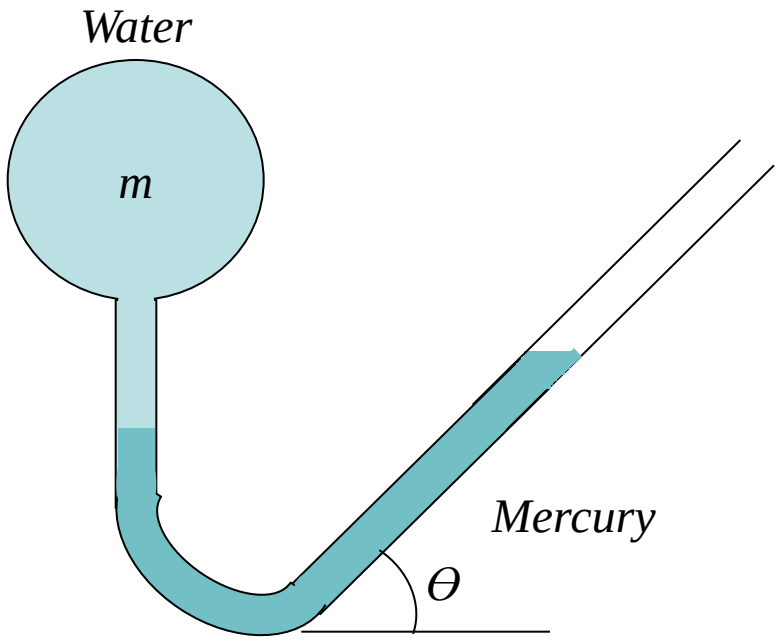
Ans: W = 61.61 kN

Pressure Measurement

Problem Set 3

Problem 5

The pressure at point m in the figure shown was increased from 70 kPa to 105 kPa. This causes the top level of mercury to move 20 mm in the sloping tube. What is the inclination, Θ?



Ans: Θ = 22.66 deg.

Pressure Measurement

Problem Set 3

Problem 6

With one end closed, a 3 m long tube is immersed vertically with the open end down into a tank of water until the open end is submerged to a depth of 1.2 m. Neglecting vapor pressure, how far will the water level inside the tube be below the water level outside the tube?

Ans: $x = 0.95\ m$